

EX. D

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Singer et al.

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(54) **SYSTEM FOR REMOVING SELECTED UNWANTED FREQUENCIES IN ACCORDANCE WITH ALTERED SETTINGS IN A USER INTERFACE OF A DATA STORAGE DEVICE**

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“High-Speed/Low-Power Selectable Optical File”, 2244 Reserarch Disclosure, Jul. 1990. No. 315.*

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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Related U.S. Application Data

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(52) **U.S. Cl.** **710/5**; 318/560; 360/73.01; 360/75; 360/78.07

(58) **Field of Search** 360/31, 75, 69, 360/73.01, 78.07; 318/560, 561; 710/1, 5, 15

(57) ABSTRACT

Techniques are provided herein for reducing vibrations in various modes of a dynamic system. One such technique comprises incorporating vibration limiting and sensitivity constraints into a partial fraction expansion equation model of the system so as to reduce vibrations to specific levels. Another technique comprises shaping a command determined using the partial fraction expansion equation model to produce a desired output. The entire command may be shaped or only selected portions thereof which produce vibrations. Another technique involves commanding in current to produce saturation in voltage. By doing this, it is possible to command voltage switches. The times at which the switches occur can be set to reduce system vibrations. Other techniques are also provided. These include varying transient portions at the beginning, middle and/or end of a move and using Posicast inputs, among others.

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15 Claims, 28 Drawing Sheets

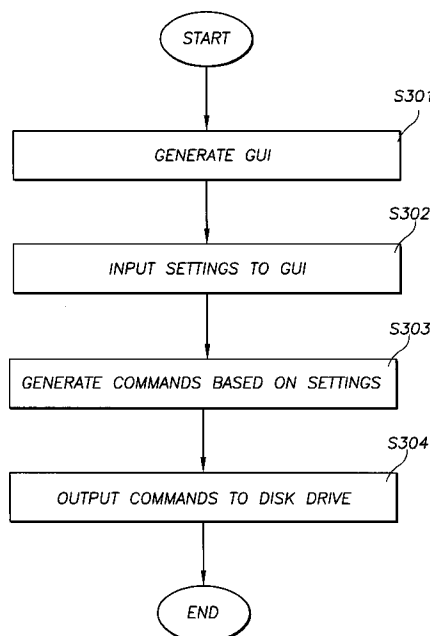


FIG. 10A

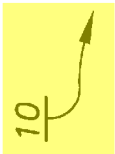
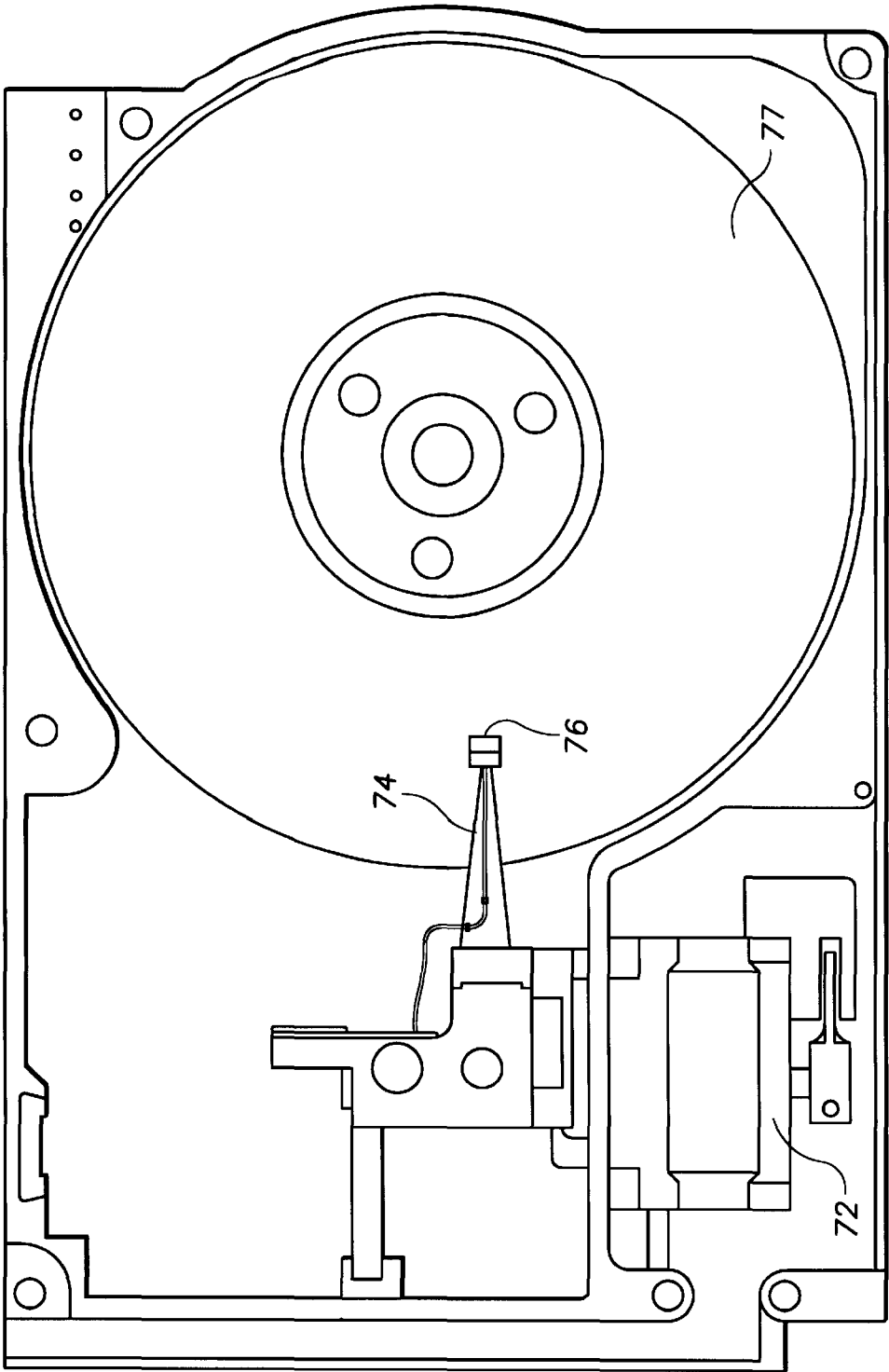
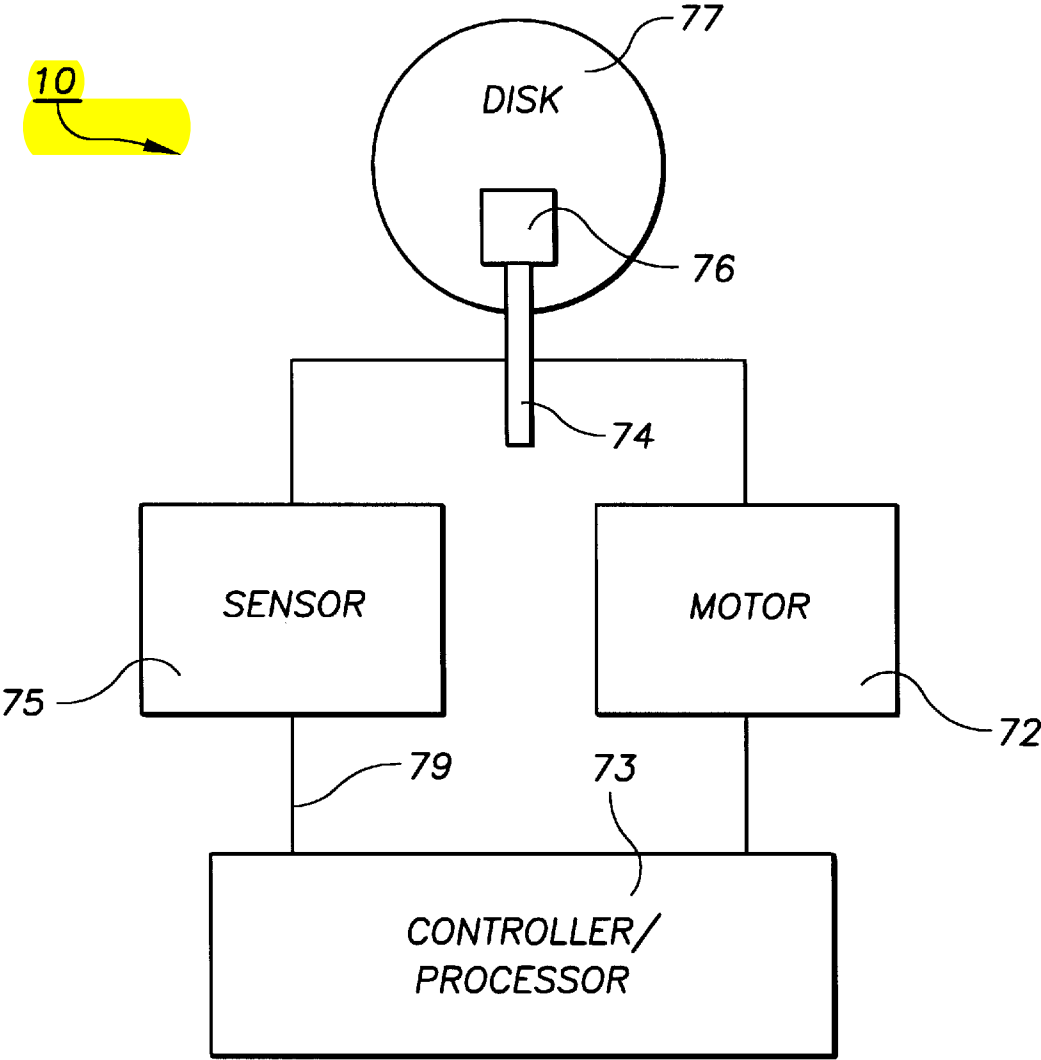


FIG. 10B



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formed locally or remotely via network interface 4. That is, the GUI may be displayed on a remote networked PC, and the settings therefor applied to the local PC. In any event, once the new parameter setting are input in step S302, they may be confirmed via "OK" button 60, canceled via "Cancel" button 61, or applied to the disk drive via "Apply" button 62. The difference between "OK" button 60 and "Apply" button 62 is that "OK" button 60 merely stores the new settings in memory (e.g., memory 11), whereas "Apply" button 62 applies the settings to the disk drive, overriding any previous hardware or software settings.

Next, in step S303, commands (e.g., electrical signals) are generated for controlling disk drive 10 in accordance with the settings set in the GUI. Exactly how these commands are generated may vary, depending upon the way in which the disk drive is controlled. Assuming, for illustration's sake, that the disk drive is being controlled via Input Shaping™, step S303 comprises convolving various inputs to the disk drive with predetermined functions which are selected based on settings in the GUI in order to produce disk drive inputs that achieve the results specified in the GUI. These functions may be stored, e.g., in memory 11 or in another memory on the system. Sections 2 to 11 below describe a variety of methods that may be used to control operation of the disk drive, any of which may be used in step S303 based on the GUI setting and other factors.

Once the necessary commands have been generated, processing proceeds to step S304, wherein these commands are provided to control operation of the disk drive. Thereafter, a user may again alter the drive's operation simply by calling up a GUI using, e.g., mouse 7, and entering desired operational parameters. Following step S304, processing ends.

At this point, it is noted that the GUI is not limited to the combinations of features shown in the figures. That is, a GUI may be generated in step S301 with includes any one or more of the foregoing features, subject to certain constraints inherent in the system. Likewise, additional features not described herein, but which are well known to those skilled in the art, may also be included in the GUI. As an alternative to the GUI, or to supplement the GUI, the disk drive may include one or more electro-mechanical manual switches for controlling all or part of the drive's operation in the manner set forth above. For the purposes of the present invention, a "jumper" is considered to be within the definition of electro-mechanical manual switch.

2.0 System Control

The following control methods are preferably implemented via computer-executable process steps in disk drive engine 16 so as to effect high-speed moves in a disk drive, such as drive 10. However, it is noted that these methods are not limited to use with disk drives. Rather, the methods described herein can be used to control any type of dynamic system which moves from one state to another state. In fact, any unwanted dynamic behavior that can be quantified in a mathematical expression can be reduced by the present invention. For example, using the present invention, a disk drive in a Redundant Array of Independent Drives ("RAID") can be commanded to move in less time than has heretofore been possible without substantially exciting neighboring drives and while simultaneously reducing acoustic vibrations that result in noise. The designer simply need select which vibrations or dynamic behavior is troublesome, identify constraints and, using the technology presented herein, choose from among several approaches for generating optimal or near optimal moves that reduce those vibrations or dynamic behavior. As used herein, the term "vibrations" can refer to mechanical and/or acoustic vibrations that cause noise.

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FIGS. 10A and 10B show close-up views of disk drive 10.

As shown, disk drive 10 includes voice coil motor 72 having a rotor (not shown), actuator arm 74, sensor 75, and head 76. These components are controlled via disk drive engine 16, or portions thereof, running on a controller/processor 73. This processor may comprise processor 25 set forth above or, alternatively, a separate controller dedicated to the disk drive which receives commands from processor 25. Head 76 reads to, and writes from, tracks (not shown) on magnetic disk 77 installed in drive 10. Actuator arm 74, on which head 76 is mounted, controls the motion of head 76 between the tracks on magnetic disk 77. Motor 72 drives actuator arm 74 in accordance with control signals received from processor 73. These control signals are generated based, at least in part, on a desired position of head 76 and an actual measured position of head 76 provided via signal 79. Movement of head 76 from an initial position to the desired position occurs within the device's seek time. The seek time for disk drive 10 comprises the time it takes for head 76 to move from an initial position to rest at a position where head 76 can perform a read/write operation on a particular track of magnetic disk 77.

The seek time for computer disk drive 10 can be reduced by commanding a component in disk drive 10, such as head 76, to move from one location to another while satisfying constraints on mechanical vibrations, acoustic vibrations, drive mounting vibrations, or any combination of constraints, physical limitations, and/or parameter variations. Several different methods for reducing such vibrations are described below in detail. One such technique involves altering system inputs that are specified as a function of time. Another technique involves generating a position-versus-velocity (hereinafter "PV" or "position-velocity") table using dynamic elements, e.g., constraints or the like, so as to produce PV table trajectories which result in reduced vibrations. In this regard, the terms "input" and "trajectory" may refer to either a reference command for a controller to follow or a feedforward signal within the controller. Still another technique involves modifying the current industry-standard PV table so that an improved PV table is constructed and used. Several methods for generating PV tables are also provided, together with ways to use an Input Shaper™ in combination with a PV table in order to reduce unwanted vibrations. Also presented are several modifications to the foregoing embodiments which have differing levels of optimality and ease of implementation.

Processor 73 determines which of these techniques to apply based on a variety of factors, such as user inputs to the GUI and the identity of the disk drive. For example, time can be traded off against amount of vibration reduction and robustness to parameter variation. In a given application, the amount of vibration reduction required to make end-of-move conditions acceptable can be a function of the movement distance or other parameter. When this is the case, it is advantageous to trade-off shaping time against shaper effectiveness (meaning amount of vibration reduction) such that (i) vibrations, both mechanical and acoustic, are reduced to an acceptable level (not excessively attenuated), and (ii) shaping time is less than it would be if the vibration were excessively attenuated. When more vibration reduction is required, a longer shaper can be used; when less vibration reduction is required a shorter shaper can be used; and when no vibration reduction is required, then no shaper (zero length) can be used. In this example, shaper selection was from among a discrete collection of shapers. It is also possible to use a single adjustable shaper, e.g. one in which the time interval between pulses is shortened; resulting in a desired shorter shaping time and reduced vibration reduction.

combination of thereof. Moreover, although the invention has been described in the context of computer disk drives, it may apply equally to other types of data storage devices (of which a computer disk drive is one), including, but not limited to, optical drives, tape drives, dual-actuated disk drives, and holographic storage devices which read from, and write to, data storage media other than magnetic disks.

The present invention has been described with respect to particular illustrative embodiments. It is to be understood that the invention is not limited to the above-described embodiments and modifications thereto, and that various changes and modifications may be made by those of ordinary skill in the art without departing from the spirit and scope of the appended claims.

What is claimed is:

1. User interface for operatively working with a processor to affect operation of a data storage device, the user interface comprising:

means for providing settings for controlling one of a seek time of the data storage device and an acoustic noise level of the data storage device in inverse relation;

means for indicating to the data storage device that one of the seek time settings of the data storage device and the acoustic noise level settings of the data storage device has been altered; and

means for causing the processor to output commands to the data storage device to alter seek trajectory shape by shaping input signals to the data storage device to reduce selected unwanted frequencies from a plurality of frequencies in accordance with the altered settings in the user interface.

2. A user interface according to claim 1, comprising a sliding bar which moves along a continuum on which data storage device acoustic noise level and seek time vary inversely, the continuum including a first end comprising a high acoustic noise level/low seek time and a second end comprising a low acoustic noise level/high seek time.

3. A user interface according to claim 1 further comprising a display area which displays discrete values corresponding to the acoustic noise level and/or the seek time of the data storage device.

4. A user interface according to claim 1 comprising discrete values which are selectable to alter the acoustic noise level and/or the seek time of the data storage device.

5. A user interface according to claim 1 wherein settings in the user interface override previous settings in the data storage device.

6. A user interface according to claim 1 further comprising a preview setting, the preview setting causing the data storage device to operate an acoustic noise level set in the user interface.

7. A method of controlling operation of a data storage device, comprising:

generating a user interface, the user interface controlling one of a seek time of the data storage device and an acoustic noise level of the data storage device;

altering settings in the user interface for one of the seek time and the acoustic noise level of the data storage device in inverse relation; and

outputting commands to the data storage device to alter seek trajectory shape by shaping input signals to the data storage device to reduce selected unwanted frequencies from a plurality of frequencies in accordance with the altered set in the user interface.

8. Computer-executable process steps stored on a computer-readable medium, the computer-executable pro-

cess steps to control operation of a data storage device, the computer-executable process steps comprising:

code to generate a user interface, the user interface controlling one of a seek time of the data storage device and an acoustic noise level of the data storage device;

code to alter settings in the user interface for one of the seek time and the acoustic noise level of the data storage device in inverse relation; and

code to output commands to the data storage device causing the data storage device to alter seek trajectory shape by shaping input signals to the data storage device to reduce selected unwanted frequencies from a plurality of frequencies in accordance with the altered settings in the user interface.

9. Apparatus for controlling operation of a data storage device, the apparatus comprising:

a memory which stores computer-executable process steps; and

a processor which executes the process steps so as (i) to generate a user interface, the user interface controlling one of a seek time of the data storage device and an acoustic noise level of the data storage device, (ii) to alter settings in the user interface for one of the seek time and the acoustic noise level of the data storage device in inverse relation, and (iii) to output commands to the data storage device causing the data storage device to alter seek trajectory shape by shaping input signals to the data storage device to reduce selected unwanted frequencies from a plurality of frequencies in accordance with the altered settings in the user interface.

10. Method of controlling operation of a data storage device, comprising:

providing a user interface for controlling one of a seek time of the data storage device and an acoustic noise level of the data storage device;

operating the user interface so as to alter settings of one of the seek time and the acoustic noise level of the data storage device in inverse relation; and

outputting commands to the data storage device causing the data storage device to alter seek trajectory shape by shaping input signals to the data storage device to reduce selected unwanted frequencies from a plurality of frequencies in accordance with the altered settings.

11. A disk drive operatively controlled by a user interface, said user interface providing settings capable of altering one of a seek time of the disk drive and acoustic noise level of the disk drive in inverse relation, and indicating to the disk drive that one of the seek time settings of the disk drive and the acoustic noise level settings of the disk drive has been altered, the disk drive comprising:

means for performing a seek operation, the seek operation generating a plurality of frequencies; and

means for outputting commands to alter seek trajectory shape by shaping input signals to the means for performing the seek operation to reduce selected unwanted frequencies from said plurality of frequencies in accordance with the altered settings in the user interface.

12. The disk drive of claim 11 wherein the user interface comprises discrete values which are selectable to alter the acoustic noise level and/or the seek time of the disk drive.

13. The disk drive of claim 11 wherein a setting in the user interface overrides a previous setting.

14. Computer-executable process steps stored on a computer-readable medium, the computer-executable pro-